CEMENT
AND
CEMENT MANUFACTURE

PUBLISHED 20TH OF EACH MONTH. PRICE 1/- A COPY. ANNUAL SUBSCRIPTION 12s. POST FREE.

PUBLISHED BY
CONCRETE PUBLICATIONS LIMITED,
20, DARTMOUTH STREET, LONDON, S.W.1.
TELEPHONE: WHITEHALL 4881.
TELEGRAPHIC ADDRESS:
CONCRETIUS, PARL, LONDON.

PUBLISHERS OF
"CONCRETE & CONSTRUCTIONAL ENGINEERING"
"CONCRETE BUILDING & CONCRETE PRODUCTS"
"CEMENT & CEMENT MANUFACTURE"
"THE CONCRETE YEAR BOOK"
"CONCRETE SERIES" BOOKS, ETC.

VOLUME 9. NUMBER 6. JUNE 1936

Investigations on a Slurry Drier or Calcinator.

By W. GILBERT, Wh.Sc., M.Inst.C.E.

(1) The Chinnor Portland Cement & Lime Company commenced operations at Chinnor, Oxfordshire, in 1928 with one wet-process rotary kiln. Under normal working conditions the clinker output averaged 5.5 tons per hour, and the standard coal consumption was 27 per cent. The slurry moisture averaged 39 per cent. A M.I.A.G. calcinator (or independent slurry drier) was added in 1934, and as a result the clinker output rose to 7 tons per hour and the standard coal consumption fell to 22.2 per cent. These figures are mainly based on a test, lasting for one week, which was made by Mr. A. A. Short, the works manager.

After describing the added plant, the author will show that the increase in output from the kiln is consistent with the reduction in the moisture content of the raw material fed to it. An account is given of the manner in which heat is transmitted from the hot gases to the material in the calcinator, and the part played by the iron bodies with which the calcinator is charged is investigated. The gases leaving the calcinator pass through two cyclone dust-collectors; the smallest particle size which these will intercept is approximately calculated, and compared later with the actual size of the dust particles which pass up the kiln chimney.

The New Plant

(2) A sectional elevation of the calcinator, together with the feed end of the kiln and the kiln flues, is shown in *Fig.* 1. The calcinator had to work in conjunction with the existing flues, and an entirely new plant could be more easily arranged. The calcinator consists mainly of a slowly rotating drum the circumference of which is built up of cast-iron rings (V) spaced 3 in. apart and secured by longitudinal bars. It carries a 47 per cent. charge of cast-iron filling bodies which are shown conventionally in *Fig.* 1. Their actual shape is such that they do not

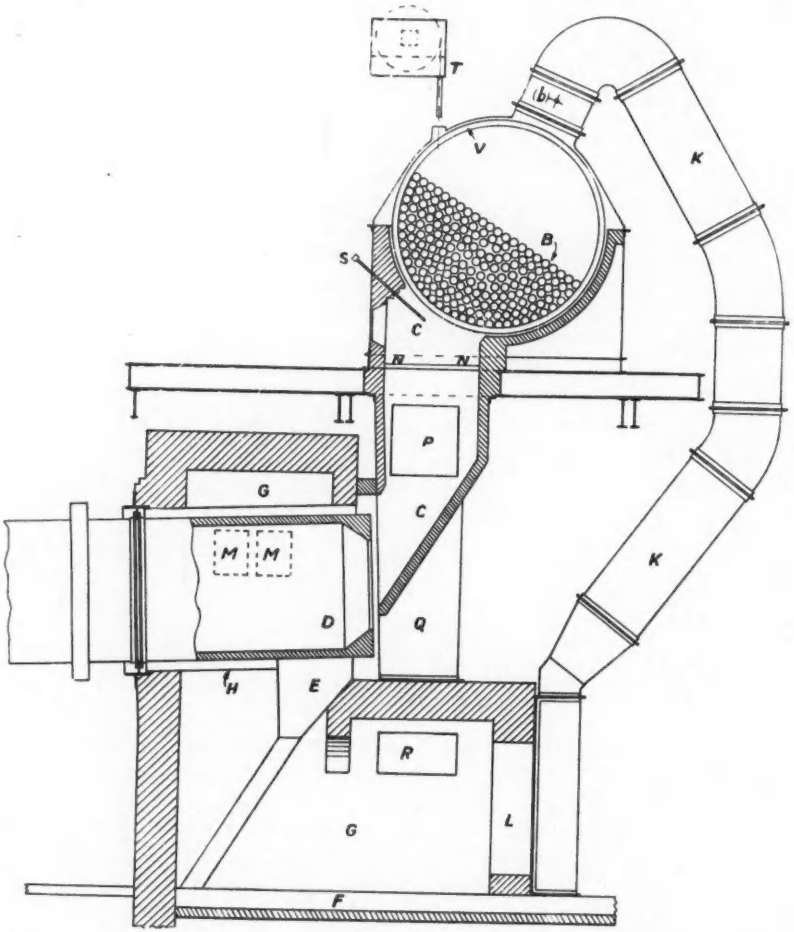

Fig. 1.

pack closely, and hence offer little resistance to the passage downwards of the raw material or to the passage upwards of the hot gases from the kiln.

The slurry is measured by a rotary spoon-feeder of the usual type and delivered to a longitudinal trough (T). From the trough 16 vertical jets spaced about $3\frac{5}{8}$ in. apart are taken to feed the calcinator, the slurry entering between the rings (V). The trough is provided with an emergency overflow. As the slurry falls through the interstices between the filling bodies a large proportion of the moisture is evaporated, and the semi-dry material falls down the feed chute (C)

and enters the rotary kiln (D). Any spill over at the kiln end passes down the chute (E) and is removed by a conveyor (F). The kiln end (D) is isolated from the flues (G) by a tube (H).

The kiln gases rise through the feed chute and the interstices of the filling bodies and then pass through the exhaust pipe (K) and the opening (L) to the flues (G). The gases are drawn from the kiln flues and enter the twin dust cyclones through two openings (MM) which are shown dotted.

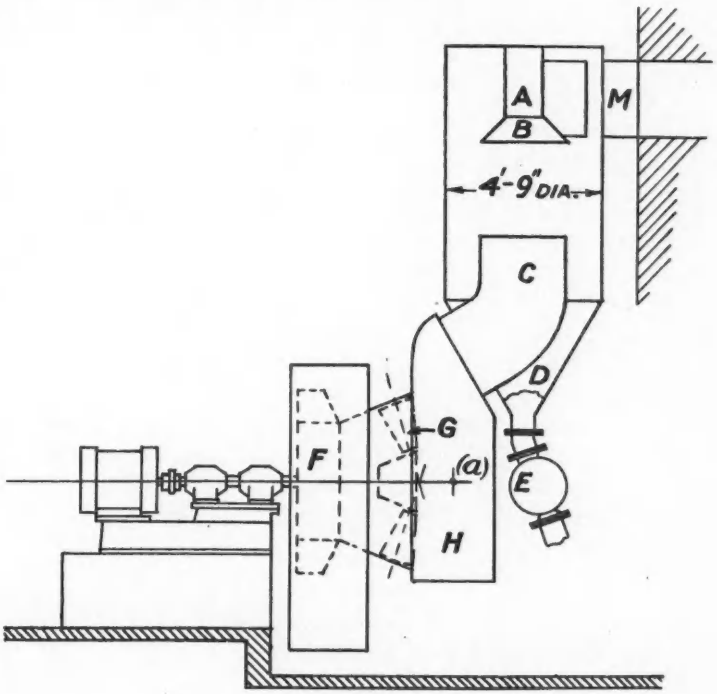

Fig. 2.

The calcinator can be isolated when required by inserting cast-iron plates through the opening (NN). Slurry is then fed directly to the kiln, and the kiln gases are drawn from the feed chute (C) through two openings (P) and pipes (Q) arranged one on each side. The gases enter the kiln flues by two openings (R) and leave through the two openings (MM) as before. Isolating dampers are provided in the pipes (Q).

(3) An elevation of the twin dust-cyclones with induced-draught fan is shown in *Fig.* 2. Each cyclone draws the dust-laden gases from the kiln flues through an opening (M). The dust is removed from each cyclone by a power-driven rotary

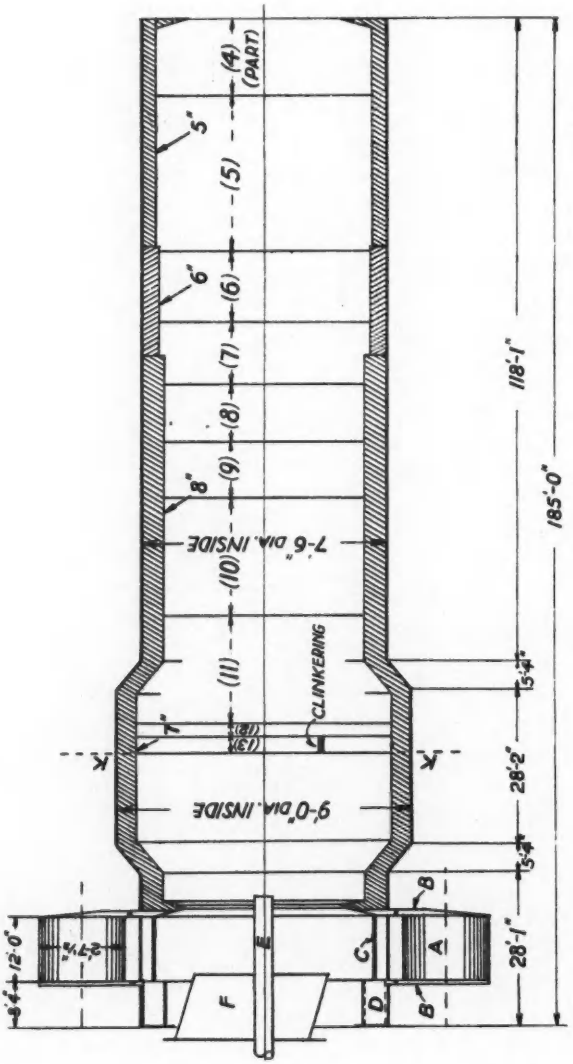
(4) (PART)
5"
(5)
6"
(6)
(7)
(8)
(9)
8"
7'-6" DIA. INSIDE
(10)
(11)
CLINKERING
7"
(12)
(13)
K
K
9'-0" DIA. INSIDE
B
A
C
D
E
F
B
12'-0"
2'-7½"
118'-1"
185'-0"
15'-4"
28'-2"
5'-4"
28'-1"

FIG. 3.

valve, and after being mixed with the dust removed from the kiln flues it is elevated and delivered to the kiln feed chute. The gases from the cyclones pass by an exhaust pipe (C) to a collecting chamber (H) and thence to an induced-draught fan (F). The fan delivers on the underside, by an inclined trunk, to a chimney 5 ft. square inside and 75 ft. high.

The kiln was originally provided with induced draught, but a larger fan delivering to the existing chimney was installed with the calcinator. The dust cyclones had to be fitted into the relatively small space between the new fan and the kiln flues, and this was successfully accomplished.

Kiln and Cooler.

(4) A sectional elevation of the kiln and cooler shell, drawn to a vertical scale which is six times the horizontal scale, is shown in *Fig.* 3. The main tube is generally 7 ft. 6 in. in diameter inside the shell plates and 185 ft. long. There is an enlarged clinkering zone 9 ft. in diameter inside and 28 ft. 2 in. long. The kiln shell extends for some distance beyond the lower end of the enlarged zone, and this portion is used as a cooler. Originally it was lined with firebrick for part

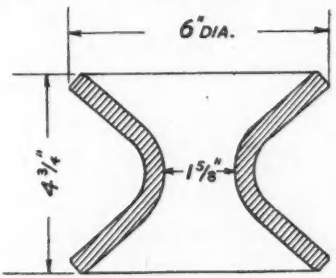

Fig. 4.

of the length, the remainder being fitted with cast-iron lifters. To deal with the increased output of clinker due to the calcinator, six cooling tubes, each 31½ in. in diameter and 12 ft. long, were added (see A, *Fig.* 3). The tubes are lined with cast-iron plates for nearly half their length; they are air cooled at the back and provided with lifters to cascade the hot clinker. The remaining portion of each tube is provided with channel-shape lifters secured to the shell. The clinker enters and leaves each tube by passages marked B. Part of the hot clinker does not pass through the new cooling tubes but travels down the main tube over cast-iron lining plates (C) which extend for 12 ft. These plates are also air cooled at the back. The remainder of the main tube is provided with cascading channels (D).

The coal-firing pipe (E) projects 24 ft. into the kiln end. It is surrounded and supported by a shield tube (F) which is attached to the kiln hood.

As shown in *Fig.* 3, clinker is made about 3 ft. beyond the centre of the enlarged zone and 28 ft. from the end of the coal-firing pipe (E). The kiln is inclined at 1 in 24 and the normal speed is 1.2 revolutions per minute.

The Calcinator.

(5) The cast-iron rings (V) are approximately 10 ft. 8 in. in diameter inside and 4 in. by 1 in. in cross-section. The length of the drum inside is 6 ft. 10 in.

A type of filling body not liable to fill up with dried slurry has to be found by trial. A good form is shown in *Fig.* 4. It is of cast iron, about $\frac{7}{16}$ in. thick, maximum diameter 6 in., depth $4\frac{3}{4}$ in., weight 5.9 lb., volume reckoned solid 63 cu. in., and surface area (outside only) 77.6 square inches.

It is found by trial that in the calcinator there will be 10.9 filling bodies per cubic foot of charge. Their volume, reckoned solid, will be 10.9×63, or 687 cubic inches, hence the volume of the interstices per cubic foot of charge will be 1,728 —687 or 1,041 cubic inches, that is 60 per cent.

The volume of the calcinator drum inside the grate bars is approximately 611 cu. ft.; hence a charge of 47 per cent. will require $10.9 \times 0.47 \times 611 = 3{,}130$ filling bodies. The weight of the charge will be $3{,}130 \times 5.9 = 18{,}470$ lb.

(6) The calcinator is supported on rollers and driven at 1.5 revolutions per minute by a motor direct coupled to a gear-box. The power consumption is from 15 to 18 E.H.P. It is estimated that 7.4 B.H.P. will be required to turn the calcinator at 1.5 revolutions per minute against a charge weight, including material, of 19,000 lb., the centre of gravity of which is displaced 1.36 ft. from the vertical centre line of the calcinator. The difference is presumably due to motor losses and the frictional losses in the gearing and bearings of the calcinator.

The rate of delivery from the calcinator was obtained in various positions. A sheet-iron box measuring 6 in. each way inside was mounted on the end of a length of pipe and inserted through each of the door openings shown in *Fig.* 1. The quantity caught in nine positions during a measured interval of time was weighed. It was found that about 75 per cent. of the material came down within a few inches of the back wall. Over most of the discharge area where the delivery was small the moisture in the material averaged 8.5 per cent., but near the back wall it averaged 20.8 per cent.

Making allowance for the variable delivery, and taking into account the dry dust collected by the cyclones, the average moisture in the material leaving the calcinator was 18 per cent. The corresponding slurry moisture was 39 per cent. It is possible that some variation in the calcinator speed, and in the size and shape of the filling bodies, might give a more uniform discharge, which would lead to a further reduction of the gas temperature when leaving the filling bodies, and to some increase in output.

Dust Cyclones and Induced-draught Fan.

(7) Referring to *Fig.* 2, each of the two cyclones is 4 ft. 9 in. in diameter. The dust-laden gases enter tangentially by the rectangular trunks (M) at a speed of 54 ft. per second, and circulate in the first instance around the central cylinder (A) and the cone piece (B), the effect of the latter being to guide the dust particles outwards and downwards. In the middle portion of each cyclone, where a free vortex is formed, the speed of rotation at any point should vary inversely as the radius. A dust particle is urged radially outwards by the action of centrifugal force, and it tends to flow inwards with the gases to reach the exhaust pipe (C).

After estimating the velocity of rotation of the gases around the circumference of the exhaust pipe (C), and applying Stoke's law, which is based on viscosity, it appears that all particles larger in diameter than 0.002 in., or 51 microns, ought to be intercepted. The makers of the cyclones are grading a sample of the dust which passes up the kiln chimney, and the result will shortly be available. The subject is further investigated in Appendix I.

The dust intercepted falls into the conical hopper (D) and it is extracted by the power-driven rotary valve (E), the total quantity (as measured during one test of two hours) being 320 lb. per hour.

(8) The induced-draught fan (F) is 67¼ in. in diameter; it is driven by a squirrel-cage motor at 580 revolutions per minute, the periphery speed being 10,200 ft. per minute. Since the speed cannot be altered it was necessary to estimate in the first instance the total water gauge which the fan would have to produce and to provide the correct periphery speed by choosing a suitable diameter for the fan. Should a fan in practice produce too much water gauge the usual method of reduction is by a damper. This does not, however, reduce the total water gauge produced, but merely wastes some of it. In this installation damper control is replaced by vane control. Pivoted vanes, marked (G) in *Fig.* 2, are provided in the fan inlet, and when the vanes are partly closed the gases passing them are caused to rotate in the same direction as the fan. As a result the total water gauge produced by the fan is reduced, and the B.H.P. required is less than it would be in the case of damper control. The turbo vane arrangement is, of course, more applicable to a large power station where the output required from any induced-draught fan may be extremely variable.

The E.H.P. supplied to the fan motor is 43. It will be seen later that the fan passes 27,340 cu. ft. of gases per minute at a total water gauge of 5.13 in. The work done on the gases, see reference (*a*), is

$$\frac{27{,}340 \times 5.13 \times 5.2}{33{,}000} = 22.1 \text{ H.P.}$$

Hence the combined efficiency of the fan and motor is

$$\frac{22.1 \times 100}{4.3} = 51.5 \text{ per cent.}$$

The fan was supplied for an output of 30,000 cu. ft. of gases per minute at 6 in. water gauge.

Data for Calculation Purposes.

(9) Various particulars relating to the working of the kiln and calcinator which will be required for calculation purposes are as follows.

KILN—

(*a*)	Clinker per minute (at 7 tons per hour)	261 lb.
(*b*)	Standard coal per minute	58 ,,
(*c*)	Standard coal per 100 lb. clinker	22.2 ,,
(*d*)	Air required per pound of coal (net)	9.91 ,,
(*e*)	Excess air used in kiln	4.0 per cent.
(*f*)	Moisture in raw material entering kiln	18.0 ,,
(*g*)	$CaCO_3$ from raw material per 100 lb. clinker	117.1 lb.
(*h*)	CO_2 from raw material per 100 lb. clinker	51.6 ,,
(*i*)	Temperature of gases leaving kiln	1,225 deg. F.
(*j*)	Temperature of clinker leaving cooler	500 ,,

CALCINATOR—

(*k*)	Moisture in slurry entering calcinator	39.0 per cent.
(*l*)	,, ,, per 100 lb. clinker	97.1 lb.
(*m*)	,, ,, leaving calcinator	18.0 per cent.
(*n*)	,, ,, per 100 lb. clinker	33.3 lb.
(*o*)	Temperature of gases entering charge	1,176 deg. F.
(*p*)	Temperature of gases leaving charge	299 ,,
(*q*)	Excess air in gases passing through charge	12.2 per cent.
(*r*)	Temperature of gases in pipe above calcinator at point (*b*) in *Fig.* 1	262 deg. F.
(*s*)	Excess air at point (*b*)	55 per cent.

(10) COAL ANALYSIS.—Standard coal (or dry coal of 12,600 B.T.U. per pound) is assumed, and the analysis [see reference (*b*)] is carbon 73.5 per cent., hydrogen 4.7 per cent., nitrogen 1.4 per cent., sulphur 1.9 per cent., oxygen 7.5 per cent., and ash 11.0 per cent.

For the method of calculating items (*d*), (*g*), (*h*), (*l*) and (*n*), also the weight of the kiln gases per pound of coal, see reference (*c*).

It is assumed that the clinker contains 1 per cent. of coal ash, and that the chimney-dust loss amounts to 1½ per cent. of the clinker produced. No allowance is made for heat supplied from the combustion of organic matter, since it was not in this instance apparent.

WEIGHT OF KILN GASES PER POUND OF STANDARD COAL.

(*a*)	CO_2 from combustion	2.70 lb.
(*b*)	H_2O ,, ,,	0.43 ,,
(*c*)	N_2 ,, ,,	7.75 ,,
(*d*)	Excess air (passing through kiln)	0.40 ,,
(*e*)	Excess air (passing through calcinator)	1.21 ,,
(*f*)	CO_2 from raw material	2.33 ,,
(*g*)	Steam from slurry in gases leaving kiln	1.50 ,,
(*h*)	Steam from slurry in gases leaving calcinator	4.38 ,,

The difference between lines (*d*) and (*e*) is due to a leakage of cold air into the chute between the calcinator and the kiln.

(11) GAS TEMPERATURE LEAVING FILLING BODIES.—This temperature could not be measured directly since the calcinator is in motion, but it can be deduced from the temperature observed in the pipe above the calcinator [at point (*b*) in *Fig.* 1] by taking into account the increase in the excess air between the two positions, see items (*q*), (*r*) and (*s*) in para. (9). Most of the leakage took place through the openings, which are large in diameter, where the revolving trunnions of the calcinator pass into the fixed casing.

The total heat of the kiln gases at point (*b*) per pound of coal used has been worked out, and in Table 1, cols. 1 and 11 to 13 it is seen to be 985 B.T.U. Since there is practically no loss by external radiation the gases leaving the filling bodies must have the same total heat per pound of coal. The figures in cols. 8 to 10 show accordingly that the gas temperature leaving the filling bodies, as found by trial, is 299 deg. F. For the heat content per pound of the kiln gases at various temperatures see reference (*d*).

(12) HEAT SUPPLY TO MATERIAL IN CALCINATOR.—Measurements show that the partly-dried raw material leaves the calcinator at an average temperature of about 212 deg. F. In the calcinator the whole of the moisture is raised to 212 deg. F., but only a portion of it is evaporated.

TABLE 1.

HEAT CONTENT OF THE KILN GASES, IN VARIOUS POSITIONS, EXPRESSED IN B.T.U. PER POUND OF STANDARD COAL USED.

Gas.	At kiln exit end. Gas temperature 1,225 deg. F.			Entering calcinator charge. Gas temperature 1,176 deg. F.			Leaving calcinator charge. Gas temperature 299 deg. F.			At point (*b*) in pipe above calcinator. Gas temperature 262 deg. F.		
	Weight of gas per lb. of coal. lb.	Heat content per lb. of gas. B.T.U.	Total heat of gas per lb. of coal. B.T.U.	Weight of gas per lb. of coal. lb.	Heat content per lb. of gas. B.T.U.	Total heat of gas per lb. of coal. B.T.U.	Weight of gas per lb. of coal. lb.	Heat content per lb. of gas. B.T.U.	Total heat of gas per lb. of coal. B.T.U.	Weight of gas per lb. of coal. lb.	Heat content per lb. of gas. B.T.U.	Total heat of gas per lb. of coal. B.T.U.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
CO_2	5.03	268	1,347	5.03	255	1,282	5.03	50.0	252	5.03	42.2	212
H_2O	1.93	493	952	1.93	466	899	4.81	42.5	204	4.81	24.4	117
N_2	7.75	293	2,272	7.75	281	2,176	7.75	59.6	461	7.75	50.4	390
Air	0.40	284	114	1.21	271	328	1.21	57.7	70	5.45	48.8	266
	15.11	—	4,685	15.92	—	4,685	18.80	—	987	23.04	—	985

NOTE.—The heat content of the gases CO_2, N_2 and air is reckoned above 60 deg. F. The heat content of the H_2O is reckoned above 212 deg. F.

DETAIL OF HEAT SUPPLY EXPRESSED IN B.T.U. PER 100 LB. OF CLINKER.

	B.T.U.
(*a*) 100 lb. of raw material raised from 60 to 212 deg. F. ($\phi = 0.25$) ..	3,800
(*b*) 51.6 lb. of CO_2 (incorporated) do. do. ($\phi = 0.21$)	1,646
(*c*) 97.1 lb. of water raised from 60 to 212 deg. F.	14,760
(*d*) 63.8 lb. of water evaporated from and at 212 deg. F.	61,890
Total	82,096

Since the kiln uses 22.2 lb. of standard coal per 100 lb. of clinker, the heat supply to the material in the calcinator can be expressed as

$$\frac{82,096}{22.2} = 3,698 \text{ B.T.U. per pound of coal used.}$$

(13) GAS TEMPERATURE ENTERING FILLING BODIES.—From Table 1, col. 10, the gases leaving the calcinator filling bodies contain 987 B.T.U. per pound of coal, hence the corresponding heat content on entering the filling bodies must be 3,698 + 987 = 4,685 B.T.U. This heat content is consistent with a gas temperature of 1,176 deg. F. as shown by cols. 5 to 7 of Table 1.

A pyrometer consisting of a thermo-couple in a steel sheath is fixed within a few inches of the underside of the calcinator drum (the reference letter is S in *Fig.* 1). The indicator usually reads about 980 deg. F. Since the true gas temperature is estimated to be 1,176 deg. F. the pyrometer reading is about 196 deg. F. too low, the error being due to the relatively low temperature of the surrounding surfaces.

The underside of the calcinator drum is at a temperature of about 250 deg. F. and the material leaving it is at 212 deg. F.; also the walls of the kiln feed chute near by have their surface temperature reduced to some extent by the proximity of the calcinator. The pyrometer stem is heated by convection, the gas velocity being 24 ft. per second; it is also heated by radiation from the gases CO_2 and H_2O. It is cooled by black body radiation to the surrounding surfaces, hence it takes up and indicates an intermediate temperature. Calculation shows that the error of the pyrometer is explained if the average temperature of the surrounding surfaces is taken at 685 deg. F., and this assumption is seen to be reasonable.

(14) GAS TEMPERATURE LEAVING KILN.—There is a leakage of cold air into the feed chute between the kiln and the calcinator, hence the gas temperature at the exit end of the kiln is greater than the gas temperature at the entrance to the filling bodies. Since there is practically no loss of heat by external radiation the heat content of the gases per pound of coal will be the same in each position, and from Table 1, cols. 1 to 7 it is seen that the gas temperature leaving the kiln is 1,225 deg. F.

(15) It is now possible to draw up a heat balance for the kiln and calcinator combination. The exit-gas temperature is that leaving the filling bodies, or 299 deg. F., and the excess air is 12.2 per cent. [see para. (9) items (*p*) and (*q*)]. The heat quantities are expressed in pounds of standard coal per 100 lb. of clinker. For method of calculation see reference (*e*).

HEAT BALANCE FOR KILN AND CALCINATOR.

Exit-Gas temperature 299 deg. F.

(All heat quantities are reckoned above 60 deg. F.)

	Per cent.
(*a*) Decomposition of 117.1 lb. of $CaCO_3$	7.24
(*b*) Slurry moisture, 97.1 lb. raised from 60 to 212 deg. F.	1.17
(*c*) do. do. evaporated at 212 deg. F.	7.46
(*d*) do. do. superheated to 299 deg. F.	0.33
(*e*) Loss in products of combustion and in excess air at 299 deg. F.	2.06
(*f*) Loss in CO_2 from raw material at 299 deg. F.	0.21
(*g*) Radiation loss from kiln	2.34
(*h*) Radiation loss from cooler	1.87
(*i*) Heat loss in clinker leaving cooler at 500 deg. F.	0.87
Total	23.55
Deduct heat supplied by exothermic reaction, standard value	1.35
Kiln standard coal consumption per cent.	22.20

The kiln and cooler radiation losses were not measured on the site, but have been approximately calculated. When working out the rate of heat transmission to the material in the kiln the temperature of the inner surface of the firebrick lining is determined in each stage. Given also the thickness and the conductivity of the firebrick the kiln shell temperature can be obtained, and hence the shell radiation loss, see references (*f*) and (*g*). The kiln radiation is estimated from section KK on *Fig.* 3, where clinkering is complete, to the upper end of the kiln. The calculation of the radiation from the cooler shell which extends from section KK to the lower end of the cooler is approximate only. It will be seen that the quantities in the heat balance add up correctly to the coal consumption

of the kiln, and it may be that the quantity assigned for kiln and cooler radiation includes some small heat losses not otherwise accounted for.

(16) Since the cooler is assumed to commence at section KK on *Fig.* 3 it is apparent that heat will be radiated into it from the flame in stages (12) and (11). The amount has been approximately calculated, and it is included in the cooler heat balance. The heat quantities are again expressed in pounds of standard coal per 100 pounds of clinker, or more simply as percentages.

HEAT BALANCE FOR COOLER.

			Per cent.
Heat out.—			
(*a*) Radiation loss from cooler shell			1.87
(*b*) Hot clinker loss			0.87
(*c*) Hot air supplied to kiln (by difference)			2.45
			5.19
Heat in.—			
(*d*) Heat content of 100 lb. of clinker falling from 2,450 to 60 deg. F. (Mean specific heat 0.258)	4.90		
(*e*) Radiation from flame into cooler end, through section KK on *Fig.* 3	0.29	5.19	

Gas Volumes, Temperatures and Draughts.

(17) Various particulars which relate to the passage of the kiln gases through the calcinator, the exhaust piping, the kiln flues, the cyclones, and the fan, are set down in Table 2.

TABLE 2.—CALCINATOR SYSTEM.

Position.	Gas temperature. deg. F.	Excess air.		Gas volume in cu. ft. per min. at 32 deg. F.	Draught in inches of water.
		Per cent.	In lb. per lb. of coal.		
	(1)	(2)	(3)	(4)	(5)
(1) Inside kiln at feed end	1,225	*4.0*	0.40	13,880	—
(2) In feed chute below filling bodies..	1,176	*12.2*	1.21	14,450	*0.67*
(3) In calcinator above filling bodies..	299	12.2	1.21	14,450	1.27
(4) In pipe above calcinator at point (b) on *Fig.* 1	*262*	*55.0*	5.45	17,510	*1.81*
(5) At entrance to kiln flues	—	55.0	5.45	17,510	*2.24*
(6) Inlet trunks of dust cyclones ..	*248*	76.0	7.54	19,010	*3.55*
(7) Vane chamber near fan inlet at point (a) on *Fig.* 2	*248*	*76.0*	7.54	19,010	*5.44*
(8) At chimney base	—	—	—	—	*0.31*

NOTE.—Quantities printed in italics were obtained by actual measurement.

Col. (1).—The method of calculating the temperatures in lines (1), (2) and (3) has already been explained ; the remaining temperatures were taken by a mercury-in-glass thermometer. At relatively low temperatures such as 250 deg. F. the pyrometer error due to radiation from it to colder surroundings is usually very small.

Col. (2).—Several measurements were made by the Orsat apparatus to obtain the figures in each of lines (1), (2), (4) and (7). It will be seen that there is a small air leakage into the kiln-feed chute, a rather large leakage into the calcinator casing (which does not pass through the filling bodies), and a smaller leakage (less than usual) into the kiln flues.

Col. (3).—These figures are obtained from col. (2), the air actually required per pound of coal being 9.91 lb., see para. (9) item (*d*).

Col. (4).—The weight of the kiln gases per pound of coal used for any line in the table can be obtained from para. (10), using the appropriate quantity of excess air. The coal used per minute is 58 lb. [see para. (9) item *b*], and the gas volumes in cubic feet per pound at 32 deg. F. are $CO_2 = 8.10$, $H_2O = 19.60$, $N_2 = 12.81$, and air = 12.39. If the gas composition and weight do not change the volume is proportional to the absolute temperature. For instance, the gas volume entering the fan per minute at the actual temperature of 248 deg. F., see line (7), is

$$\frac{19{,}010 \times (248 + 461)}{32 + 461} = 27{,}340 \text{ cu. ft.}$$

Col. (5).—With the exception of line (3) all the draughts given in col. (5) were carefully measured, care being taken to eliminate any effect due to velocity. The draught in line (3) was obtained by deducting from the draught in line (4) the water gauge lost at the junction between the exhaust pipe and the calcinator casing. The loss was substantial since the entrance is not bell mouthed. The actual water gauge lost in the calcinator charge was therefore only 1.27 − 0.67 = 0.60 inch.

(18) The water gauge required to draw the kiln gases through each section of the kiln and calcinator plant is as follows:

Static water gauge lost in—	
(*a*) Kiln, cooler, and feed chute	0.67
(*b*) Calcinator filling bodies	0.60
(*c*) Calcinator exhaust piping	0.97
(*d*) Kiln flues	0.20
(*e*) Dust cyclones	3.00
Total	5.44

The total water gauge required could be appreciably reduced by bell-mouthing the entrances to the calcinator exhaust piping and to the cyclone feed-trunks. There is also a substantial loss of water gauge at the entrance to the cyclone exhaust pipe.

With reasonable care in design it appears that a total water gauge of 4.0 to 4.25 in. should be sufficient for a kiln and calcinator plant.

(19) REFERENCES TO PREVIOUS ARTICLES IN *Cement and Cement Manufacture*.

(*a*) Calculation of fan horse-power, 1936, February, page 37; (*b*) An analysis of standard coal, 1935, August, p. 190; (*c*) Calculation of air required per pound of coal, and of slurry moisture, and CO_2 per clinker ton, 1930, November, pp. 1472–3; (*d*) Heat content of kiln gases per pound at various temperatures, 1933, August, p. 263; (*e*) Calculation of heat balance for kiln, 1930, November, p. 1479; (*f*) Heat transmission through fire-brick lining, 1930, September, p. 1201; (*g*) Table of radiation loss from kiln shells, 1930, July, p. 946.

APPENDIX I.

Estimation of the Diameter of the Smallest Particle which the Dust Cyclones will Intercept.

(20) The estimation is made by the aid of Stoke's law, which determines the uniform velocity attained by a very small particle when falling through a fluid at rest. It is the law on which the graduation of particle size by sedimentation is based.

Let V = velocity of particle in feet per second.
ρ_1 = specific gravity of particle (water = 1.0).
ρ_2 = specific gravity of fluid medium (water = 1.0).
θ = coefficient of viscosity of fluid in poises (c.g.s. units).
d = particle diameter expressed in units of one ten-thousandth of an inch.

then $d = 2{,}944 \times \sqrt{\frac{V \times \theta}{\rho_1 - \rho_2}}$ .. .. (1)

For air at 60 deg. F. .. .. $\theta = 1.80 \times 10^{-4}$
For air at 248 deg. F. .. .. $\theta = 2.24 \times 10^{-4}$
For wet process kiln gases at 248 deg. F. .. .. $\theta = 1.94 \times 10^{-4}$

The value of θ for kiln gases was suggested by the National Physical Laboratory.

(21) We may first apply Stoke's law to determine the maximum diameter of a dust particle which can be carried up the kiln chimney. The chimney is 5 ft.

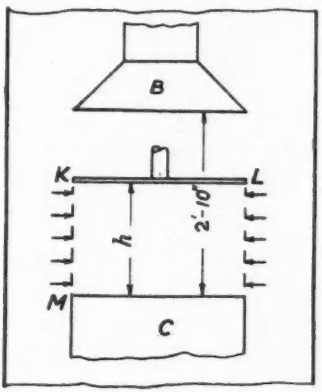

Fig. 5.

square inside, and the gas quantity is 27,340 cu. ft. per minute at 248 deg. F. The corresponding velocity in feet per second is 18.2. The value of ρ_1 for a dry particle of raw material may be taken at 2.0, and the value of ρ_2 for kiln gases is small enough to be neglected, hence

$$d = 2{,}944 \times \sqrt{\frac{18.2 \times 1.94}{10{,}000 \times 2.0}} = 124 \text{ units.}$$

That is, $d = 0.0124$ inch.

Such a particle would just pass a 50^2 sieve.

(22) Turning now to the dust cyclones, part of one interior is reproduced in *Fig.* 5 where B is the cone piece and C the exhaust pipe. To assist the calculation a plate (KL) of the same diameter as the exhaust pipe, and capable of movement vertically, is added. The circumferential area (KM) through which the gases must pass in order to enter the exhaust pipe is supposed to be covered with perforated plate in order to equalise the gas flow over the entire area.

Let R_0 = radius of cyclone = 2.375 ft.
R_i = radius of exhaust pipe = 1.33 ft.
V_0 = gas velocity in circle at radius R_0 in feet per second.
V_i = gas velocity in circle at radius R_i in feet per second.
V_r = radial component of gas velocity at surface KM.
Q = cubic feet of gas per second = 228.
h = distance of plate (KL) above the exhaust pipe in feet.

The gases enter the cyclone tangentially at a velocity of 54 ft. per second, and later they are assumed to form a free vortex in the space between the circumferential surface (KM) and the circumference of the cyclone. In a free vortex the velocity in the circle at any point will vary inversely as the radius. Allowing for a loss of velocity energy in the gas stream of 20 per cent. between the entrance to the cyclone and the vortex, it is found that $V_i = 65$ and $V_0 = 38$.

The value of V_r is $\dfrac{Q}{2\pi R_i h}$

If h is taken provisionally at 1.0, then $V_r = 27.2$.

The dust particles are prevented from entering the exhaust pipe through the circumferential area (KM) by centrifugal force, and at the radius R_i its value is

$$CF = \frac{W \times (V_i)^2}{g \times R_i} = \frac{W \times (65)^2}{32.2 \times 1.33} = 98\,W.$$

That is, the centrifugal force acting on a particle will be 98 times the weight.

(23) Since the value of V_r (for $h = 1.0$) is 27.2, the diameter of a particle which would just not enter the exhaust pipe is the same as the diameter of a particle of density $98\rho_1$ which would fall through the fluid medium (gas) at rest at a velocity of 27.2 feet per second. Hence, applying Stoke's law we have for $h = 1.0$

$$d = 2{,}944 \times \sqrt{\frac{27.2 \times 1.94}{10{,}000 \times 98 \times 2}} = 15.3 \text{ units.}$$

The true value of h is not known, but the effect of varying it is shown below.

h feet.	V_r feet per second.	d units.
0.75	36.2	17.7
1.0	27.2	15.3
1.5	18.1	12.5
2.0	13.6	10.8

From the table it seems reasonable to assume, as a preliminary to research, that the diameter of the smallest particle which the cyclones will remove comes between 10 and 20 units. The particle size will be realised by remembering that the aperture width of a 170^2 sieve is 35 units.

It is of interest to note that if cyclones were dispensed with and a large chimney used as a settling chamber the gas velocity by Stoke's law would have to fall to 0.27 feet per second in order to deposit all particles larger than 15 units in diameter. The chimney would then require to be 41 ft. square. Hence the advantage of a cyclone as compared with a dust settling chamber is manifest.

(*To be continued.*)

Heat of Hydration of Partially Prehydrated Cements.

THE following note is from the Technical News Bulletin of the United States National Bureau of Standards.

The importance of preventing excess temperature development within mass concrete at the time of construction, when the hydration of the cement is evolving heat, is generally recognised. The temperature can be kept within the desired limits by the use of an expensive integral cooling system or by reducing the heat at the source, i.e. by the use of low-heat cements. Although numerous studies have been made on methods of producing cements with low heats of hydration, very little data are available on the suitability of preparing low-heat cements by hydrating standard Portland cements with small proportions of water prior to the use of the cement.

The Bureau undertook a study to determine the effect of prehydrating two different types of cements with steam at atmospheric pressure so that approximately 3 and 5 per cent. of water, as determined by the loss on ignition of the resulting product, was taken up by the cements. The heat of hydration was determined by the heat of solution method, using a calorimeter identical with that developed by the Bureau for the routine testing of the cements for use in Boulder Dam. The test ages were 7, 28, and 90 days, and 1 year. Three curing conditions were used: (1) Standard curing (70 deg. F. for length of test); (2) simulated adiabatic curing (70 deg. F. for the initial 24 hours, then at 150 deg. F. to end of test); and (3) a combination of these two methods wherein at the respective ages of 7, 28, and 90 days specimens were removed from 150 deg. F. storage and put in the 70 deg. F. storage for the remainder of a year.

It was found that prehydration with 3 per cent. of water reduced the average heat of hydration of the standard Portland cements cured at 70 deg. F. by 14, 12, and 6 per cent. for the respective ages of 7 and 28 days and 1 year. Prehydration with 5 per cent. of water reduced the average heat of hydration of the same cements cured at the same temperature by 28, 27, and 16 per cent. respectively for the ages of 7 and 28 days and 1 year. Under the conditions of simulated adiabatic storage (150 deg. F. after the initial 24 hours) the same order of decrease in the heat of hydration was effected by the two prehydrations as was found at the 70 deg. F. storage.

The prehydrations of the high-early-strength cements caused only about two-thirds the decrease in the average heat of hydration as was found for the same prehydration of standard Portland cements.

It appears, therefore, that considering only the heat of hydration values, a low-heat cement can be prepared by prehydrating a standard Portland cement with approximately 5 per cent. of water. The prehydration also very materially improved the resistance of the cement to sodium-sulphate solution as measured by the Merrian test.

Deterioration of Concrete Owing to Chemical Attack.

By F. M. LEA, D.Sc., F.I.C.

THE following is an abstract of a paper read at a recent meeting of the Institution of Sanitary Engineers.

The relative resistance of different types of cements to chemical attack differs widely, and it may be well first to consider briefly the various types of cements which will be mentioned later. The average contents of the main constituents of these cements are shown in Table I.

TABLE I.

PERCENTAGE COMPOSITIONS OF CEMENTS.

	Normal Portland cement.	Rapid hardening Portland cement.	Aluminous cement.	Portland blast-furnace cement.	Pozzolanic cement.
Lime (CaO)	64	As normal	38	58	43
Silica (SiO_2)	21	Portland,	6	23	34
Alumina (Al_2O_3) ..	6	but slight	39	8	10
Iron oxide (Fe_2O_3) ..	3	changes in composition.	14	2	5

These cements behave chemically in distinct ways when they react with water and set and harden, and they yield different products as the result of the setting action. The difference in the resistance of the set materials to subsequent chemical attack is intimately connected with these changes in the nature of the set products. In general, when Portland cement concretes suffer chemical attack it is the free hydrated lime and the hydrated calcium aluminate which react with the aggressive agent. In Portland blast-furnace cement the compounds produced on hydration are of the same general type, but owing to the lower lime content of the cement a less amount of free hydrated lime is formed. With pozzolanic cements, the Portland cement present hydrates in the normal manner, but the free hydrated lime liberated reacts further with the pozzolana to form compounds in which the lime is combined. The amount of free hydrated lime left in a pozzolanic cement concrete after maturing and ageing is therefore much lower than with Portland cement concrete, and may be almost zero. Aluminous cement is relatively low in lime and high in alumina content, and when it hydrates it forms principally hydrated compounds of lime and alumina together with free hydrated alumina. This latter product is inert to most of the chemically destructive agents to which concretes may normally become subject, and probably forms a film over the surface of the more reactive hydrated compounds of lime and alumina, thus protecting them from attack. It seems that a corresponding film formation may occur in pozzolanic cements, and that the hydrated com-

pounds of lime and alumina present in set pozzolanic cements are protected by being covered with the products of the reaction between the uncombined calcium hydroxide and pozzolana.

Sulphate Salts.

The sulphate salts most commonly found in soils are calcium sulphate (gypsum), magnesium sulphate, sodium sulphate and potassium sulphate, but other sulphate salts may sometimes be present as a result of contamination with trade waste products. Sulphate salts also occur in sea water, but the subject of deterioration of concrete in sea water is not dealt with in this paper.

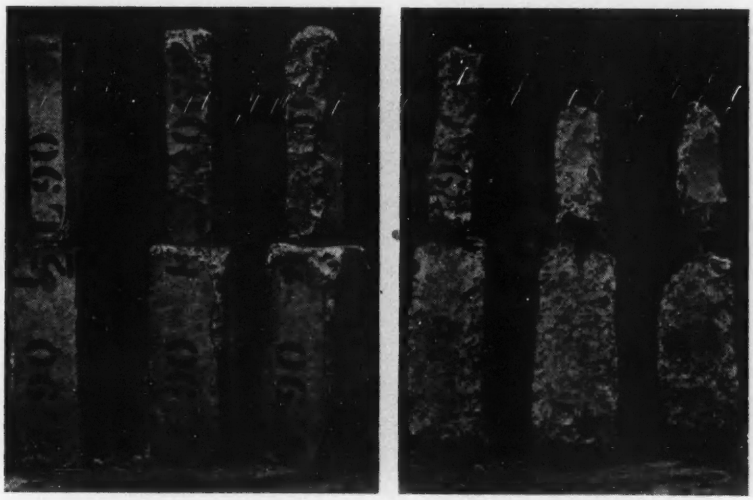

FIG. 1.—1 : 2 : 4 PORTLAND CEMENT CONCRETE PRISMS AFTER STORAGE FOR ONE YEAR IN 5 PER CENT. MAGNESIUM SULPHATE SOLUTION. THE SLUMP OF THE ORIGINAL CONCRETE IS SHOWN UNDER THE SPECIMENS.

In general, sulphate salts react with the hydrated calcium aluminates to form calcium sulphoaluminate, which occupies a greater volume than the original material and the formation of which tends to cause expansion and disruption of the concrete. The uncombined calcium hydroxide also reacts with sulphate salts, other than calcium sulphate, to form calcium sulphate, and the crystallisation of this compound in the concrete also causes expansion and disintegration. A certain amount of gypsum is added to Portland cement during grinding to control the setting time, but there are two reasons why this does not cause deterioration. First the amount of gypsum added is limited by the British Standard Specification to a maximum amount equivalent to a content of 2.75 per cent. sulphur trioxide ; and, second, the reaction between the gypsum added and the cement is rapid and takes place mainly while the concrete or mortar is still plastic.

The resistance of Portland cement concrete to attack by sulphate salts increases with the density and watertightness of the material, while concrete which is aged before exposure to attack is more resistant than concrete exposed at a very early age. An illustration of the influence of the density of the concrete is afforded by Fig. 1, in which are shown prisms of 1 : 2 : 4 Portland cement concrete, of slumps varying from ½ in. to 7 in., after storage for one year in a 5 per cent. solution of magnesium sulphate. The increase in the rate of attack of the concrete as the water content and slump are increased, and the density decreased, is clearly shown.

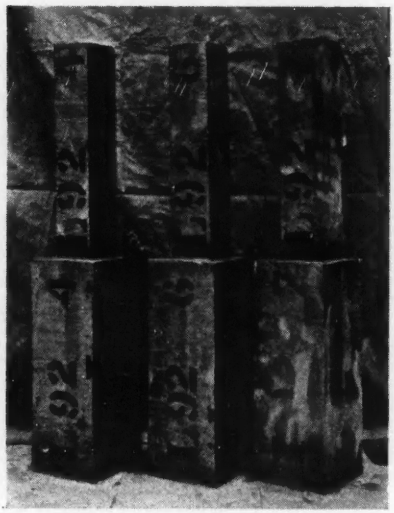

FIG. 2.—1 : 2 : 4 ALUMINOUS CEMENT CONCRETE PRISMS AFTER STORAGE FOR TWO YEARS IN 5 PER CENT. MAGNESIUM SULPHATE SOLUTION.

Aluminous cement concrete, properly made, seems from practical experience and laboratory tests extending over many years to be immune from attack by sulphate salts. It is therefore a valuable material for sulphate-resistant construction. Fig. 2 is a photograph of 1 : 2 : 4 aluminous cement concrete prisms which show no sign of deterioration after two years immersion in 5 per cent. magnesium sulphate solution. Other aluminous cement concrete specimens kept at the Building Research Station for twelve years in 5 per cent. magnesium sulphate solution are similarly free from any sign of deterioration.

Pozzolanic cements, though not so immune to sulphate attack as aluminous cement, have a much higher resistance than Portland cement and have been considerably used on the Continent. Pozzolanic cements when available commercially in this country should have a considerable sphere of usefulness under the less severe conditions of exposure to sulphate action.

Portland blast-furnace cement, either alone or blended with a pozzolana, has been widely used in European countries for sea water work.

Occurrence of Sulphate Salts in Clays.

Sulphate salts occur to some extent in most clays, but it is only in certain of them that the amounts present are sufficient to give rise to serious risk of damage to Portland cement concrete. The most commonly occurring sulphate salt in this country is calcium sulphate, known as gypsum or selenite. It occurs sporadically, often in pockets, throughout the London clay and is also found elsewhere, though it is not possible at present to give any general indication as to the regions in which it is prevalent. It may occur in clay as large rounded agglomerations of radiating crystals (Fig. 3), the nodular mass appearing grey or brown in colour though the individual crystals of which it is composed are colourless, or as small crystals scattered in the clay which can sometimes be recognised

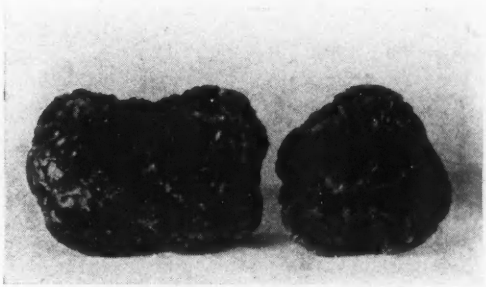

FIG. 3.—NODULAR MASS OF GYPSUM CRYSTALS.

by their shiny appearance (Fig. 4). Magnesium sulphate is known to occur in clays in some regions around London (e.g. Epsom) while sodium sulphate is also found in some parts. Both these salts are very soluble in water, much more than calcium sulphate, and their presence is sometimes indicated by a white efflorescence appearing on the surface of freshly-exposed clay when it is allowed to dry. The surface layers, up to a few feet in depth of clay soils containing sulphate salts, often contain a much lower content than is found at greater depth. This is to be attributed to the leaching of salts from the surface by rain water.

Deterioration and failure of concrete in the ground owing to sulphate attack have been recognised for very many years in the U.S.A. and in some European countries where very severe conditions exist, but it is probably correct to say that it is only within recent years that the serious nature of the problem has been appreciated in England. Concrete attacked by calcium sulphate or sodium sulphate is usually reduced eventually to a soft mush, but when magnesium sulphate is the aggressive agent the disintegrated material is often harder and more granular. The attack can usually be recognised at an earlier stage by the weakness of the concrete and the presence of white deposits within it.

The extent to which attack of Portland cement concrete occurs depends on the amount of sulphate salts present in a soil, and on the facility with which they can be transferred in solution from the surrounding soil to the surface of the concrete. The presence of water is essential, for the dry salts will not attack dry concrete. Particularly dangerous conditions may arise where one surface of a concrete is exposed to air and the other is in contact with wet soil containing sulphates, or where part of the concrete is below and part above ground. The soil waters containing the sulphate salts may then be drawn into the concrete by capillary forces, and the water passing through evaporates at

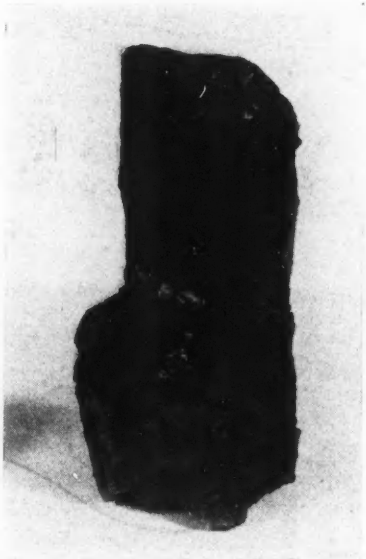

FIG. 4.—SMALL GYPSUM CRYSTALS ON SURFACE OF CLAY.

the exposed surface. The sulphate salts can in this way become concentrated within the concrete. Such an action is likely to be more serious with the very soluble sodium and magnesium sulphates than with calcium sulphate, the saturated solution of which contains only about 0.2 per cent. of the salt. With mass concrete which is entirely buried in wet soil no such continuous flow into the concrete occurs, and attack proceeds by the slower processes of diffusion. The permeability of the surrounding soil is an important factor, for unless the sulphate salts can be carried to the surface of the concrete and the supply maintained the attack cannot progress. Some results obtained in Switzerland from large scale tests on concrete pipes buried in aggressive soils are of interest in this connection. Pipes of Portland cement concrete made by six different manufacturers were buried in one area and dug up for examination after about two years. The pipes

with the densest and least permeable concrete were sound, whilst the less dense pipes had deteriorated in varying degrees. If Portland cement is to be used in areas where any danger of attack exists, it is most important that the density of the concrete should be as high as possible. In areas in which the risk is high, much recent construction has been carried out with aluminous cement concrete.

As examples of some clays and ground waters containing high contents of sulphate salts, the following data may be quoted:

(1) Clay, 2 per cent. SO_3 present mostly as gypsum; ground water, 0.1 per cent. SO_3 present mostly as gypsum. (2) Ground water, 0.3 per cent. SO_3. (3) Ground water, 0.1 per cent. SO_3 present mainly as gypsum. (4) Ground water, 0.1 per cent. SO_3 present mainly as magnesium and sodium sulphates. (5) Clay, 0.4 per cent. SO_3. In cases (1), (2) and (5), existing concrete in the ground had been reduced to a mass which could be easily broken by hand.

The following data afforded an example of a clay and ground water containing very low contents of sulphate salts: Clay, 0.01 per cent. SO_3; ground water, 0.005 per cent. SO_3. In such a soil no risk of sulphate attack is to be feared. As an intermediate case, but one not likely to cause damage to well made concrete completely buried, the following example may be quoted: Clay, 0.15 per cent. SO_3 present as gypsum; ground water, 0.015 per cent. SO_3 present as gypsum.

Pure and Acid Natural Waters.

Waters draining from many mountains and moorland areas contain only very small contents of dissolved salts, and may often be slightly acid owing to the presence of dissolved carbon dioxide and of organic acids such as humic acid arising from the decay of peat.

Pure water has a solvent action on set cement, tending to dissolve the lime and leave a residue of non-coherent silica and alumina. Under ordinary conditions with dense concretes, such an action is limited to the surface and does not penetrate into the mass. Very much trouble has, however, been experienced in Norway and Sweden with large concrete dams made with lean concrete mixes and exposed to very pure natural waters. In some cases leaching of lime from the mass of the concrete has become so pronounced as to make the dam very leaky and necessitate remedial measures. A case has been cited of the surface of the Portland cement concrete becoming attacked within one year and the aggregate exposed, though the action progressed no further. Similar action has been reported on surface renderings to reservoirs and to mortar joints in masonry, resulting even in the total disappearance of the rendering or the reduction of the mortar to a mass of loose sand.

Hard waters containing appreciable quantities of dissolved lime salts have little or no effect on good concretes, but acidic waters, when also free from dissolved salts, may have an even more aggressive action than pure waters. The acidic constituent mainly responsible is carbon dioxide, which in water forms carbonic acid, but a small amount of free sulphuric acid is also occasionally present. This is found, for example, in waters from some moorland areas in the north of England which are exposed to polluted atmospheres from surrounding industrial towns,

but its presence may also be due to the existence of easily oxidisable forms of pyrites in the soil. The oxidation of pyrites leads to the formation of an iron sulphate and free sulphuric acid. Humic acid arising from the decay of peat seems to have little action on concrete, probably because this acid forms with lime a salt which is not soluble in water. Waters which, because of their brownish colour, would be described as peaty are, however, often also very soft and contain free carbon dioxide and only small amounts of dissolved salts. It is to these two latter characteristics rather than the presence of humic acid that their aggressive action is due.

Practical experience has shown that aluminous cement concrete has a very high resistance to attack by pure waters or waters containing carbon dioxide, and experiments in Scotland show complete immunity to attack of 1 : 2 : 4 aluminous cement concrete after eleven years, under conditions where Portland cement concrete suffered surface attack with exposure of the aggregate in less than one year. Experience abroad indicates that pozzolanic cements have a higher resistance to attack than Portland cements.

Contaminated Grounds.

Chemical attack on concrete is sometimes found in grounds which have been filled or contaminated with trade wastes. Thus ground filled with clinker, ashes, or refuse, and sites previously occupied by gasworks, factories producing wastes of a type destructive to concrete, etc., may all be potentially dangerous. Clinker, brick rubble and similar material may contain appreciable amounts of soluble sulphate salts. These salts can be dissolved by water percolating through a fill of such materials and cause attack of concrete adjacent to it. In the case of a concrete retaining wall which was attacked by sulphate salts it was found that the water draining from the filling material behind it contained approximately 0.5 per cent. of sulphate salts composed of calcium, magnesium and alkali sulphates. A clinker filling from another site was found to contain well over 1 per cent. sulphur trioxide (SO_3) corresponding to some 2 per cent. of sulphate salts. The sites of disused gasworks may often be heavily contaminated with spent material from the gas purification process, sulphate salts, ammonium salts, etc. The ground water on such sites is likely to contain sulphate salts, and may also be acidic in reaction. In the case of sites formerly occupied by factories, etc., it is possible to find a wide variety of contaminating materials, but a knowledge of the nature of the processes for which the factory was used will often suggest the type of contamination which may be present. Such contamination may be quite harmless to concrete, or vary through all stages to one which is seriously damaging. Thus the sub-soil on the site of a gold refinery, long disused, was found to contain 0.01 gm. free sulphuric acid per 100 gm. soil, and up to 1 per cent. SO_3 present as copper and calcium sulphates. Mass concrete of moderately good quality in this ground showed attack up to a depth of 8 in.

Internal Attack of Sewers.

Sewer Gas.—Under certain conditions sewage may give rise to the evolution of appreciable amounts of hydrogen sulphide, and in such cases severe attack of

concrete and mortar may occur. Thus sulphate, thiosulphates, and similar salts of sulphur acids may undergo reduction to form hydrogen sulphide. The conditions which lead to the evolution of hydrogen sulphide are not clearly defined, but a high average temperature of the sewage, a high content of sulphur compounds, and a long period before the sewage reaches the outfall all favour the action. Attack of concrete by hydrogen sulphide occurs only in the presence of oxygen. The hydrogen sulphide is oxidised to form sulphurous and sulphuric acids, which attack the lime compounds in the set cement, or alternatively calcium sulphide may be formed initially and undergo oxidation with final formation of sulphates. The attack is limited to the upper part of the sewer, and that below the permanent liquid level remains unaffected. In concrete which has been attacked by sewer gas, the aggregate is exposed and the surface material is soft. In this country attack of this type is relatively rare. It seems, however, that special precautions are necessary in using mortar and concrete if the sewage contains an abnormal content of sulphur salts.

The surface treatment of concrete with solutions of bitumen or coal tar pitch, and the filling of the exposed face of mortar joints in brickwork with mixtures of tar and pitch, have been used as means of protection, but it seems questionable whether these methods afford a permanent remedy, though they may have value. Experience in California has shown that bituminous materials, where they come into contact with the sewage, tend to be emulsified by any soaps, oils, fats, etc., which may be present. The use of sand and sulphur compounds for jointing plates of burnt clay, used as an internal lining to the upper part of large sewers, has been tried, but with limited success owing to bacterial oxidation of the sulphur. Little information seems to be available on the suitability of other types of chemically resistant surface paints, e.g. synthetic resin paints, chlorinated rubber paints, for protection of concrete or mortar under the conditions considered. In general, any surface treatment is much more likely to be successful if applied in the first instance before a sewer is put into use than if used afterwards to protect concrete which has already suffered damage. Aluminous cement was tried at Cairo but, though more resistant than Portland cement, was stated not to be immune from attack. Special acid resisting cements of various types as used in the chemical industries can be obtained and, though costly, might serve for pointing brickwork.

Trade Effluents.—Trade wastes may be divided very broadly into those containing organic matter, mineral matter, or both. Organic wastes, when alkaline, should not normally have much effect on mortar or concrete. Saponifiable fats and oils can cause disintegration of Portland cement concrete, but it is not to be anticipated that with the amounts present in most trade effluents, after dilution with normal sewage, serious trouble should occur. More care seems necessary in the case of organic wastes which are acidic in reaction, owing to the presence of free organic acids, to see that no appreciable acid concentration is reached.

No cement product can be expected to withstand continued exposure to even very dilute solutions of free mineral acids, and any effluent which gives rise to such a condition in the sewage is a source of potential danger. The effect of salts depends

very largely on their composition. Many salts such as chlorides, nitrates, carbonates, and phosphates, have no deleterious effect on cement products except in solutions of very high concentration and much above those likely to be reached in practice. An exception to this general statement must be made in the case of certain ammonium salts such as ammonium nitrate, but even in this case only with relatively strong solutions, e.g. 0.5 to 1 per cent. or over, is deterioration to be anticipated. The salts which must be regarded as potentially dangerous are those of the sulphur acids, e.g. sulphates, thiosulphates, sulphites, etc. These salts may prove a source of danger through stimulating the production of hydrogen sulphide from the sewage, or by causing direct attack on Portland cement products. The rate of attack of Portland cement concrete by solutions of sulphates increases with the concentration of the solution up to about 0.5 to 1 per cent., and above this limit increases but little. Ammonium sulphate is the most aggressive of all the sulphate salts in its effect on concrete.

Improvements in Rotary Kilns for Burning Cement.

In a recent number of *Zement* (1936, p. 15) an article by H. Jordan gives a review of the patents taken out in Germany for improvements in rotary kilns for burning cements. It is illustrated with several diagrams.

INDEX TO ADVERTISERS.

Allen, Edgar, & Co.	Back Cover	Klöckner-Werke	ii
Austro-American Magnesite Company	vii	Krupp-Grusonwerk	viii
Babcock & Wilcox, Ltd.	—	Metropolitan-Vickers Electrical Co., Ltd.	—
Beard & Fitch, Ltd.	—	Miag Mühlenbau und Industrie, A.-G.	vi
British Rema Manufacturing Co., Ltd.	—	New Conveyor Co., Ltd.	—
British Thomson-Houston Co., Ltd.	—	Newell, Ernest, & Co., Ltd.	—
Brown, David, & Sons (Hudd.) Ltd.	—	Pearson, E. J. & J., Ltd.	—
Brown, John, & Thos. Firth, Ltd.	—	Polysius, G.	v
Davidson & Co., Ltd.	x	Prior Fields Foundry Co., Ltd.	—
Davison, Charles, & Co., Ltd.	—	Rolland, John, & Co., Ltd.	—
Derschow, C.	vi	Ross Patents, Ltd.	—
Firth, Thos., & J. Brown, Ltd.	—	Ruston-Bucyrus, Ltd.	—
Frere, R., & F. Evrard	—	Ruston & Hornsby, Ltd.	—
Gebr. Pfeiffer, Barbarossawerke A.-G.	—	Smidth, F. L., & Co., Ltd.	iii
Glover, W. T., & Co., Ltd.	—	Vickers-Armstrongs, Ltd.	ix, xi
Helipebs, Ltd.	Front Cover	Visco Engineering Co., Ltd.	—
Hepburn Conveyor Co., Ltd.	—		